

10/781/493

(19)



Europäisches Patentamt  
European Patent Office  
Office européen des brevets



(11) Publication number: **0 429 187 A1**

(12)

## EUROPEAN PATENT APPLICATION

(21) Application number: 90311738.0

(51) Int. Cl.<sup>5</sup>: **A61K 9/18, A61K 31/565**

(22) Date of filing: 25.10.90

The title of the invention has been amended  
(Guidelines for Examination in the EPO, A-III,  
7.3).

(30) Priority: 26.10.89 IE 3448/89

(43) Date of publication of application:  
29.05.91 Bulletin 91/22

(84) Designated Contracting States:  
AT BE CH DE DK ES FR GB GR IT LI LU NL SE

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(54) **Enhanced bioavailability adsorbates.**

(57) An enhanced bioavailability adsorbate formulation comprising an adsorbate of a mixture of a pharmaceutically useful steroid and a polyvinylpyrrolidone adsorbed on a cross-linked polyvinylpyrrolidone.

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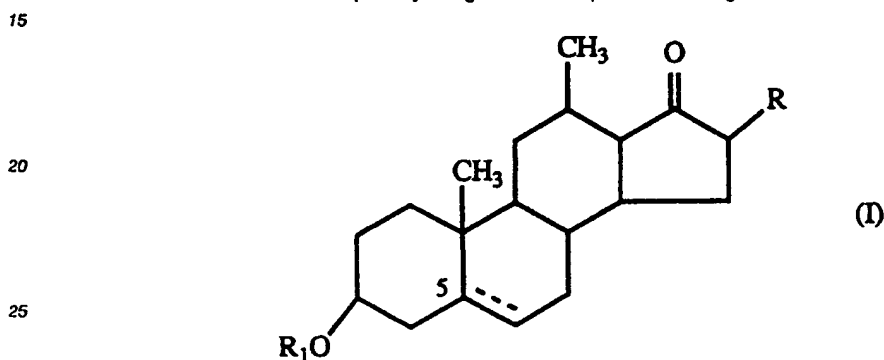
This invention relates to an adsorbate formulation for use in various drug delivery systems.

It is frequently desirable to enhance the bioavailability of an active substance from a pharmaceutical formulation in vivo. Various enhanced bioavailability pharmaceutical formulations are available which have a particular solubility profile, resulting in enhanced absorption of the active substance and, therefore, more effective medication.

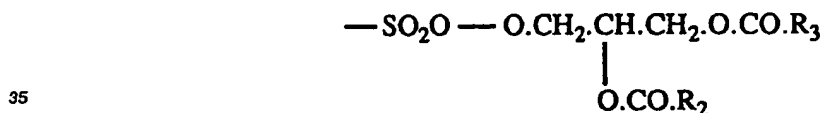
The use of many active substances in therapy is complicated by problems of poor solubility and this is especially the case with the steroid group of drugs. DHEA and like steroids and salts thereof are insoluble and exhibit poor bioavailability due to poor absorption when administered orally, thus rendering them generally unsuitable for oral administration.

It is an object of the present invention to provide enhanced bioavailability formulations and, in particular, enhanced bioavailability steroid formulations resulting from improved absorption of the steroid component of the formulations.

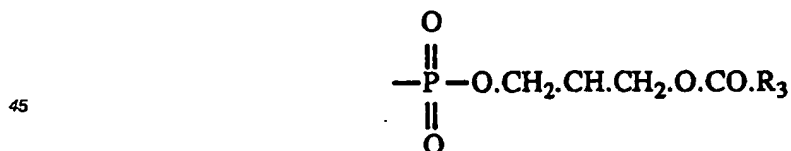
Accordingly, the invention provides an enhanced bioavailability adsorbate formulation comprising an adsorbate of a mixture of one part by weight of a compound of the general formula (I)



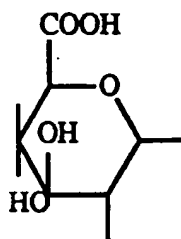
in which R is a hydrogen or bromine atom, and R<sub>1</sub> is a hydrogen atom, an SO<sub>2</sub>OM group wherein M is a hydrogen or sodium atom, a sulphatide group



wherein each of R<sub>2</sub> and R<sub>3</sub>, which may be the same or different, is a straight or branched chain alkyl radical of 1 to 14 carbon atoms, or a phosphatide group



wherein each of R<sub>2</sub> and R<sub>3</sub>, which may be the same or different, is a straight or branched chain alkyl radical of 1 to 14 carbon atoms, or a glucuronide group



and wherein the broken line represents an optional double bond, and the hydrogen atom at position 5 is present in the  $\alpha$ - or  $\beta$ -configuration or a mixture of both configurations, and from 0.1 to 10 parts by weight of polyvinylpyrrolidone, adsorbed on a cross-linked polyvinylpyrrolidone in a ratio of 1 part by weight of said mixture to 0.20 to 20 parts by weight of cross-linked polyvinylpyrrolidone.

Preferred steroids covered by the general formula (I) are dehydroepiandrosterone (DHEA) and 16 - bromoepiandrosterone or hydrates, including polymorphs, enantiomers and isomers thereof or salts thereof, especially DHEA sulphate.

The formation of the DHEA adsorbate may result in the steroid being in an amorphous state to some extent, which can be verified by x-ray diffraction and, in addition, differential scanning calorimetry, which state may be retained in the enhanced bioavailability formulations hereinafter described.

In a preferred embodiment the polyvinylpyrrolidone is present in the adsorbate in an amount of 0.1 to 2 parts by weight relative to 1 part by weight of the steroid.

Furthermore in a preferred embodiment the formulation contains 1 part by weight of said mixture relative to 0.2 to 10 parts by weight of cross-linked polyvinylpyrrolidone.

A broad range of molecular weights of polyvinylpyrrolidones may be used (Mw 10,000 - 700,000) but a preferred polyvinylpyrrolidone is one where the average molecular weight is greater than 55,000, but is especially in the range 65,000 - 250,000.

The invention also provides a process for preparing an enhanced bioavailability formulation as defined above, which comprises dissolving the steroid and the polyvinylpyrrolidone in a common solvent in which both the steroid and the polyvinylpyrrolidone are soluble, mixing the solution thereby obtained with a given quantity of the cross-linked polyvinylpyrrolidone so as to permit adsorption of said steroid and said polyvinylpyrrolidone to said cross-linked polyvinylpyrrolidone and removing the solvent.

The solvent used may be any pharmaceutically suitable common solvent in which both the steroid and the polyvinylpyrrolidone are soluble.

The solvent is suitably selected from water, alcohols, ketones, halogenated aliphatic compounds, halogenated aromatic hydrocarbon compounds, aromatic hydrocarbon compounds and cyclic ethers or a mixture thereof.

Especially preferred solvents include water, methanol, ethanol, isopropyl alcohol, acetone, methylethyl ketone, methylisobutyl ketone, hexane, heptane, methylene chloride, dichloromethane, chloroform, carbon tetrachloride, toluene, xylene and tetrahydrofuran.

The polyvinylpyrrolidone is chosen to modify the solubility of the steroid in the presence of cross-linked polyvinylpyrrolidone and may also serve to maintain a level of amorphous drug in the polymer matrix structure of the adsorbate during dissolution. Principally, the polyvinylpyrrolidone serves to aid the enhanced bioavailability of the dosage form according to the invention.

An especially preferred cross-linked polyvinylpyrrolidone is Crospovidone (sold under the Trade Marks POLYPLASDONE XL (GAF) and KOLLIDON CL (BASF)).

For manufacturing formulations according to the invention the adsorbate may be blended with suitable excipients and used as a powder or dispersible granules, or, it may be granulated and blended with a polymer or mixture of polymers or mineral material which cause the formulation to disintegrate in the presence of water, and tableted or encapsulated according to conventional methods. These formulations exhibit improved drug absorption and enhanced bioavailability. Suitable polymers for blending with adsorbates are inert polymers, which include water soluble polymers. Preferred polymeric and mineral materials which may be used include: natural starch (corn, potato, etc.) pregelatinised starch such as that sold under the Trade Mark AMIGEL, modified corn starch such as that sold under the Trade Mark STA R X 1500, sodium starch glycolate such as that sold under the Trade Marks PRIMOGEL and EXPLOTAB, sodium carboxymethylcellulose, carboxymethylcellulose, cellulose, methylcellulose, microcrystalline cellulose such as that sold under the Trade Mark AVICEL PH 101, ion exchange resins, cross-linked polyvinylpyrrolidone

(Crospovidone) such as that sold under the Trade Marks POLYPLASDONE XL and KOLLIDON CL, clays such as aluminium magnesium silicate such as that sold under the Trade Mark VEEGUM HV, bentonite, colloidal silicon dioxide such as that sold under the Trade Mark AEROSIL, alginic acid or salts thereof, and gums such as agar, guar, locust bean, karaya, pectin and tragacanth gums. Bentonite is native colloidal  
 5 hydrated aluminium silicate freed from gritty particles and consisting mainly of montmorillonite ( $\text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot \text{H}_2\text{O}$ ). Bentonite swells in water to give a homogenous mass about 12 times the volume of the dry powder.

The adsorbates according to the present invention result in improved drug delivery relative to the micronised raw material, since the adsorbates in the formulations of the present invention yield an enhanced solubility complex leading to improved absorption and bioavailability of said active drug in vivo,  
 10 and enhanced in vitro dissolution rates in excess of 1.1 times that of the micronised free steroid having a particle size less than  $10 \mu\text{m}$  (D50).

In the accompanying drawings:

Fig. 1 represents biocurves denoting plasma levels (ng/ml) for DHEA base versus time (h) for a DHEA adsorbate in accordance with the invention (curve a) and standard micronised DHEA (curve b); and  
 15 Fig. 2 represents biocurves denoting plasma levels ( $\mu\text{g/ml}$ ) for DHEA sulphate versus time (h) for a DHEA adsorbate in accordance with the invention (curve a) and standard micronised DHEA sulphate (curve b).

The invention will be further illustrated with reference to the following Examples.

#### 20 EXAMPLE 1

An adsorbate is prepared having the following composition:

25	DHEA	57.143% w/w
	Polyvinylpyrrolidone	14.286% w/w
	Crospovidone	28.571% w/w

30 The DHEA and polyvinylpyrrolidone are added to a suitable solvent such as acetone, dichloromethane or isopropanol and mixed until the solution is complete. Then the cross-linked polyvinylpyrrolidone (Crospovidone) is gradually added while mixing and the solvent evaporated. The resulting powder is reduced to obtain a finer particle size. X-ray diffraction and differential scanning calorimetry studies are  
 35 performed on the powder and demonstrate that a proportion of the DHEA may be in an amorphous or altered crystalline state. The powder thus obtained is used to make several formulations as shown in the following Examples.

#### 40 EXAMPLE 2

A powder formulation is prepared having the following composition:

45	DHEA adsorbate (prepared as in Example 1)	43.75% w/w
	Sorbitol powder U.S.P.	2.30% w/w
	Aspartame (Aspartame is a Trade Mark)	0.60% w/w
	Lactose monohydrate U.S.P.	32.65% w/w

50 The above components are blended together and then a blend equivalent to 500 mg DHEA is packaged into suitable sachets.

#### 55 EXAMPLE 3

A powder formulation is prepared having the following composition:

DHEA adsorbate (prepared as in Example 1)	21.88% w/w
Sorbitol powder U.S.P.	11.50% w/w
Aspartame	0.30% w/w
Lactose monohydrate U.S.P.	66.32% w/w

The above components are blended together and then a blend equivalent to 250 mg DHEA is packaged into suitable sachets.

#### EXAMPLE 4

A powder formulation is prepared having the following composition:

DHEA adsorbate (prepared as in Example 1)	65.624% w/w
Sorbitol powder U.S.P.	33.576% w/w
Aspartame	0.800% w/w

The above components are blended together and then a blend equivalent to 750 mg DHEA is packaged into suitable sachets.

#### EXAMPLE 5

A capsule formulation is prepared having the following composition:

DHEA adsorbate (prepared as in Example 1)	87.5% w/w
Aerosil	2.5%
Lactose monohydrate U.S.P.	10.0% w/w

The above components are blended together and then a blend equivalent to 400 mg DHEA is filled into suitable capsules.

#### EXAMPLE 6

An adsorbate formulation is prepared having the following composition:

DHEA	40.00% w/w
Polyvinylpyrrolidone	20.00% w/w
Cross-linked polyvinylpyrrolidone	40.00% w/w

The DHEA and polyvinylpyrrolidone are added to a suitable solvent such as acetone, dichloromethane or isopropanol and mixed until the solution is complete. Then the cross-linked polyvinylpyrrolidone (POLYPLASDONE XL) is gradually added while mixing and the solvent evaporated.

#### EXAMPLE 7

A tablet formulation is prepared having the following composition:

DHEA adsorbate (prepared as in Example 6)	90.00% w/w
Cross-linked polyvinylpyrrolidone	9.50% w/w
Magnesium stearate	0.50% w/w

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The above components are blended together and then compressed to form 300 mg DHEA tablets.

EXAMPLE 8

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An adsorbate is prepared having the following composition:

DHEA sodium sulphate	57.15% w/w
Polyvinylpyrrolidone	14.28% w/w
POLYPLASDONE XL	28.57% w/w

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20 The DHEA sodium sulphate and polyvinylpyrrolidone are added to a suitable solvent such as acetone, dichloromethane or isopropanol and mixed until the solution is complete. The POLYPLASIDONE XL is added gradually while mixing and the solvent is evaporated.

EXAMPLE 9

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A powder formulation is prepared having the following composition:

DHEA sodium sulphate adsorbate (prepared as in Example 8)	45.87% w/w
Sorbitol powder U.S.P.	23.00% w/w
Aspartame	0.60% w/w
Lactose monohydrate U.S.P.	30.53% w/w

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The above components are blended together and then a blend equivalent to 500 mg DHEA base is packaged into suitable sachets.

EXAMPLE 10

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A capsule formulation is prepared having the following composition:

DHEA sodium sulphate adsorbate (prepared as in Example 8)	87.50% w/w
Aerosil	2.50% w/w
Lactose Monohydrate U.S.P.	10.00% w/w

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The above components are blended together and then a blend equivalent to 250 mg DHEA base is filled into suitable capsules.

Comparison of Enhanced Bioavailability DHEA Formulation with Micronised DHEA

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In this study an enhanced bioavailability DHEA adsorbate powder of the type prepared in Example 2 was compared with standard micronised DHEA in capsule form. For the formulation in accordance with the

invention (hereinafter referred to as 'test') the dose administered was 500 mg of DHEA as adsorbate in powder-sachet form. The standard micronised DHEA (hereinafter referred to as 'reference') was administered as 2 x 250 mg capsules. The micronised DHEA used had a particle size less than 10  $\mu\text{m}$  (D50). In the study, the test substance was compared in a group of 9 healthy male human volunteers against the reference substance. The dosage regime was 500 mg every 8 hours over a 24 hour period. Plasma samples were taken in each case at intervals up to and including 24 hours post initial dosing and the samples were assayed for DHEA (base and sulphate) levels. DHEA sulphate levels were measured because a substantial portion of the DHEA is converted to the sulphate form *in vivo*. The levels were compared as shown in Table 1 and Figs. 1 and 2. For the reference substance, the area under the curve (AUC) value are arbitrarily denoted as 100%. The AUC value was then compared and assigned an absolute bioavailability value (%) using the 100% as baseline.

TABLE 1

Single Dose Data		
Comparison of the relative bioavailability of the test substance with the reference using both DHEA base and DHEA sulphate		
	REFERENCE(%)	TEST(%)
DHEA Base	*F = 100	F = 127.25
DHEA Sulphate	F = 100	F = 129.39

\*F = absolute bioavailability

Mean urinary recoveries for DHEA base for the reference and test substances are given in Table 2.

TABLE 2

Mean Urinary Recoveries for DHEA Base		
	REFERENCE (mg/24 h.)	TEST (mg/24 h.)
Day 0	22.55 $\pm$ 8.50	24.66 $\pm$ 12.30
1	460.67 $\pm$ 179.87	619.33 $\pm$ 220.54
2	799.55 $\pm$ 191.90	800.78 $\pm$ 256.10
3	745.88 $\pm$ 179.92	922.55 $\pm$ 238.52
4	694.33 $\pm$ 162.07	827.66 $\pm$ 151.50
5	800.22 $\pm$ 156.19	896.44 $\pm$ 173.27

### Claims

1. An enhanced bioavailability adsorbate formulation comprising an adsorbate of a mixture of one part by weight of a compound of the general formula (I)



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5/11/2006, EAST Version: 2.0.3.0



said mixture relative to 0.2 - 10 parts by weight of cross-linked polyvinylpyrrolidone.

5. A formulation according to any one of Claims 1 to 4, characterised in that the polyvinylpyrrolidone has an average molecular weight in the range 65,000 - 250,000.

6. A formulation according to any one of Claims 1 to 5, characterised in that the adsorbate is blended with a polymeric or mineral material which disintegrates in the presence of water.

7. A formulation according to Claim 6, characterised in that the material which disintegrates in the presence of water is selected from natural starch, pregelatinised starch, modified corn starch, sodium starch glycolate, sodium carboxymethylcellulose, carboxymethylcellulose, cellulose, methylcellulose, microcrystalline cellulose, ion-exchange resins, cross-linked polyvinylpyrrolidone, clays, alginic acid or salts thereof, and gums.

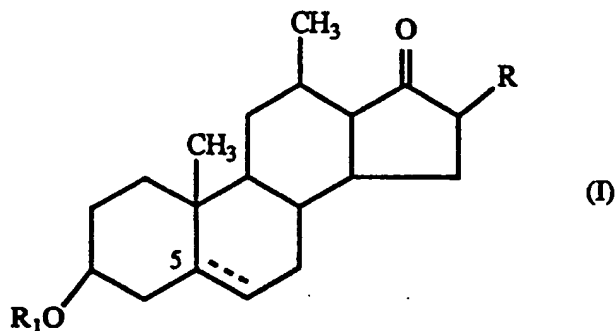
8. A process for preparing an enhanced bioavailability formulation according to any one of Claims 1 to 7, characterised in that it comprises the steps of dissolving the steroid and the polyvinylpyrrolidone in a common solvent in which both the steroid and the polyvinylpyrrolidone are soluble, mixing the solution thereby obtained with a given quantity of the cross-linked polyvinylpyrrolidone so as to permit adsorption of said steroid and said polyvinylpyrrolidone to said cross-linked polyvinylpyrrolidone and removing the solvent.

9. A formulation according to any one of Claims 1 to 7, characterised in that the *in vitro* solubility of the steroid in the adsorbate is equal to or in excess of 1.1 times the solubility of the free steroid in micronised form.

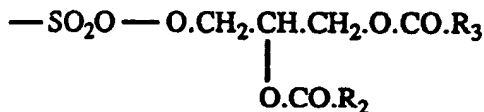
10. A formulation according to any one of Claims 1 to 7 or 9, characterised in that it is in the form of a powder, granule, tablet, capsule or suspension.

Claims for the following Contracting States: ES, GR

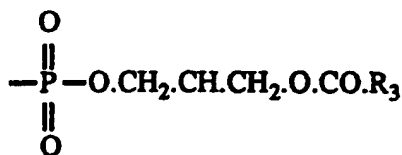
1. A process for the preparation of an enhanced bioavailability adsorbate formulation comprising an adsorbate of a mixture of one part by weight of a compound of the general formula (I)



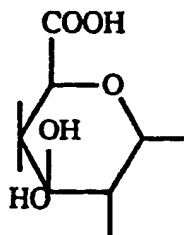
in which R is a hydrogen or bromine atom, and R<sub>1</sub> is a hydrogen atom, an SO<sub>2</sub>OM group wherein M is a hydrogen or sodium atom, a sulphatide group



wherein each of R<sub>2</sub> and R<sub>3</sub>, which may be the same or different, is a straight or branched chain alkyl radical of 1 to 14 carbon atoms, a phosphatide group



wherein each of  $R_2$  and  $R_3$ , which may be the same or different, is a straight or branched chain alkyl radical of 1 to 14 carbon atoms, or a glucuronide group



- and wherein the broken line represents a optional double bond, and the hydrogen atom at position 5 is present in the  $\alpha$ - or  $\beta$ - configuration or a mixture of both configurations, and from 0.1 to 10 parts by weight of polyvinylpyrrolidone, adsorbed on a cross-linked polyvinylpyrrolidone in a ratio of 1 part by weight of said mixture to 0.20 to 20 parts by weight of cross-linked polyvinylpyrrolidone, characterised in that it comprises the steps of dissolving the steroid and the polyvinylpyrrolidone in a common solvent in which both the steroid and the polyvinylpyrrolidone are soluble, mixing the solution thereby obtained with a given quantity of the cross-linked polyvinylpyrrolidone so as to permit adsorption of said steroid and said polyvinylpyrrolidone to said cross-linked polyvinylpyrrolidone and removing the solvent.
2. A process according to Claim 1, characterised in that the compound prepared is dehydroepiandrosterone or 16-bromoepiandrosterone, or a hydrate, polymorph, enantiomer or isomer thereof, or a salt thereof.
3. A process according to Claim 1 or 2, characterised in that the polyvinylpyrrolidone is present in the adsorbate in an amount of 0.1 - 2 parts by weight relative to 1 part by weight of the steroid.
4. A process according to any one of Claims 1 to 3, characterised in that the formulation prepared contains 1 part by weight of said mixture relative to 0.2 - 10 parts byweight of cross-linked polyvinylpyrrolidone.
5. A process according to any one of Claims 1 to 4, characterised in that the polyvinylpyrrolidone has an average molecular weight in the range 65,000 - 250,000.
6. A process according to any one of Claims 1 to 5, characterised in that the adsorbate is blended with a polymeric or mineral material which disintegrates in the presence of water.
7. A process according to Claim 6, characterised in that the material which disintegrates in the presence of water is selected from natural starch, pregelatinised starch, modified corn starch, sodium starch glycolate, sodium carboxymethylcellulose, carboxymethylcellulose, cellulose, methylcellulose, microcrystalline cellulose, ion-exchange resins, cross-linked polyvinylpyrrolidone, clays, alginic acid or salts thereof, and gums.
8. A process according to Claim 7, characterised in that the solvent used is any pharmaceutically suitable common solvent in which both the steroid and the polyvinylpyrrolidone are soluble.
9. A process according to any one of Claims 1 to 8, characterised in that the *in vitro* solubility of the steroid in the adsorbate prepared is equal to or in excess of 1.1 times the solubility of the free steroid in micronised form.
10. A process according to any one of Claims 1 to 9, characterised in that the formulation prepared is in the form of a powder, granule, tablet, capsule or suspension.

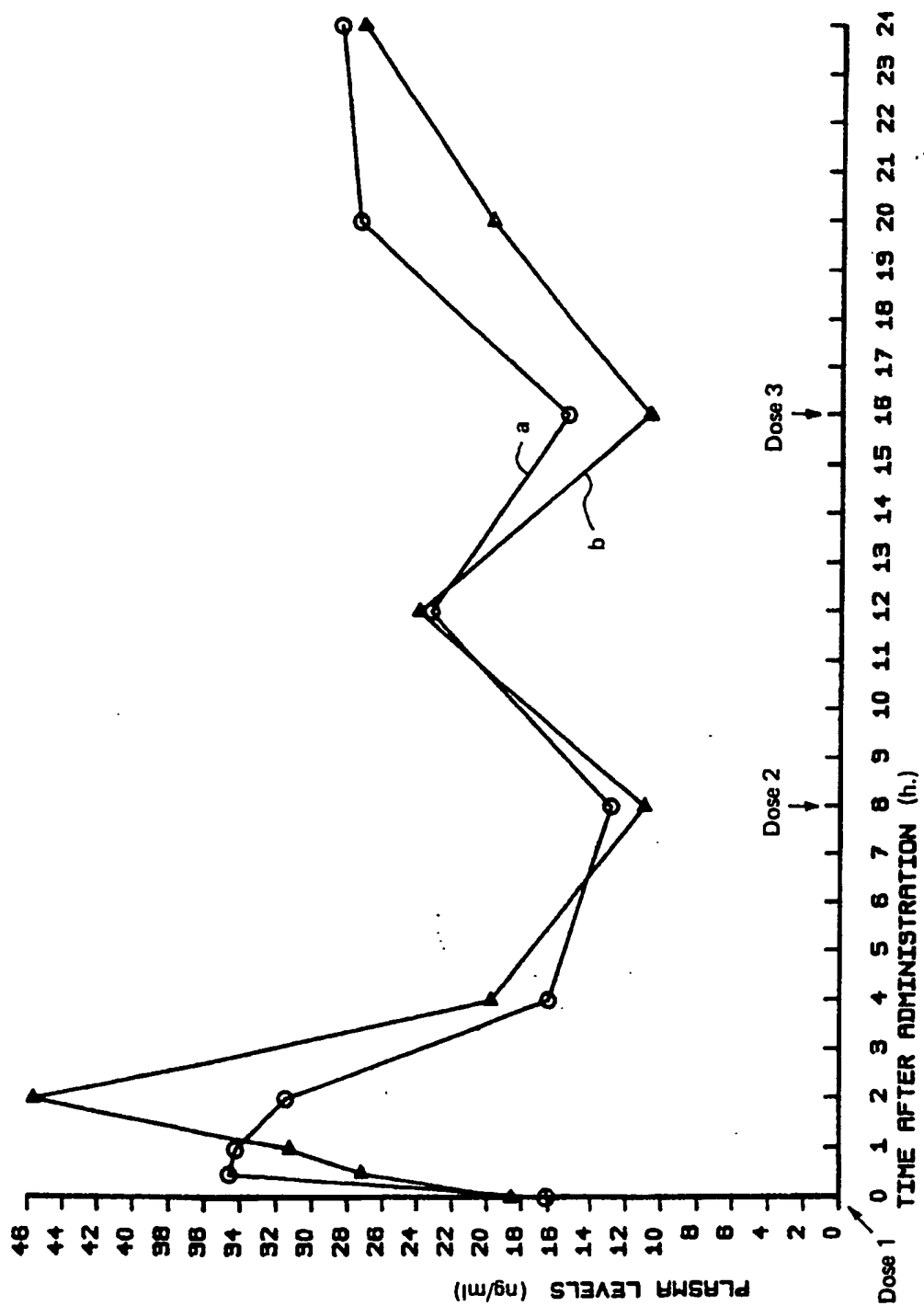


FIG. 1

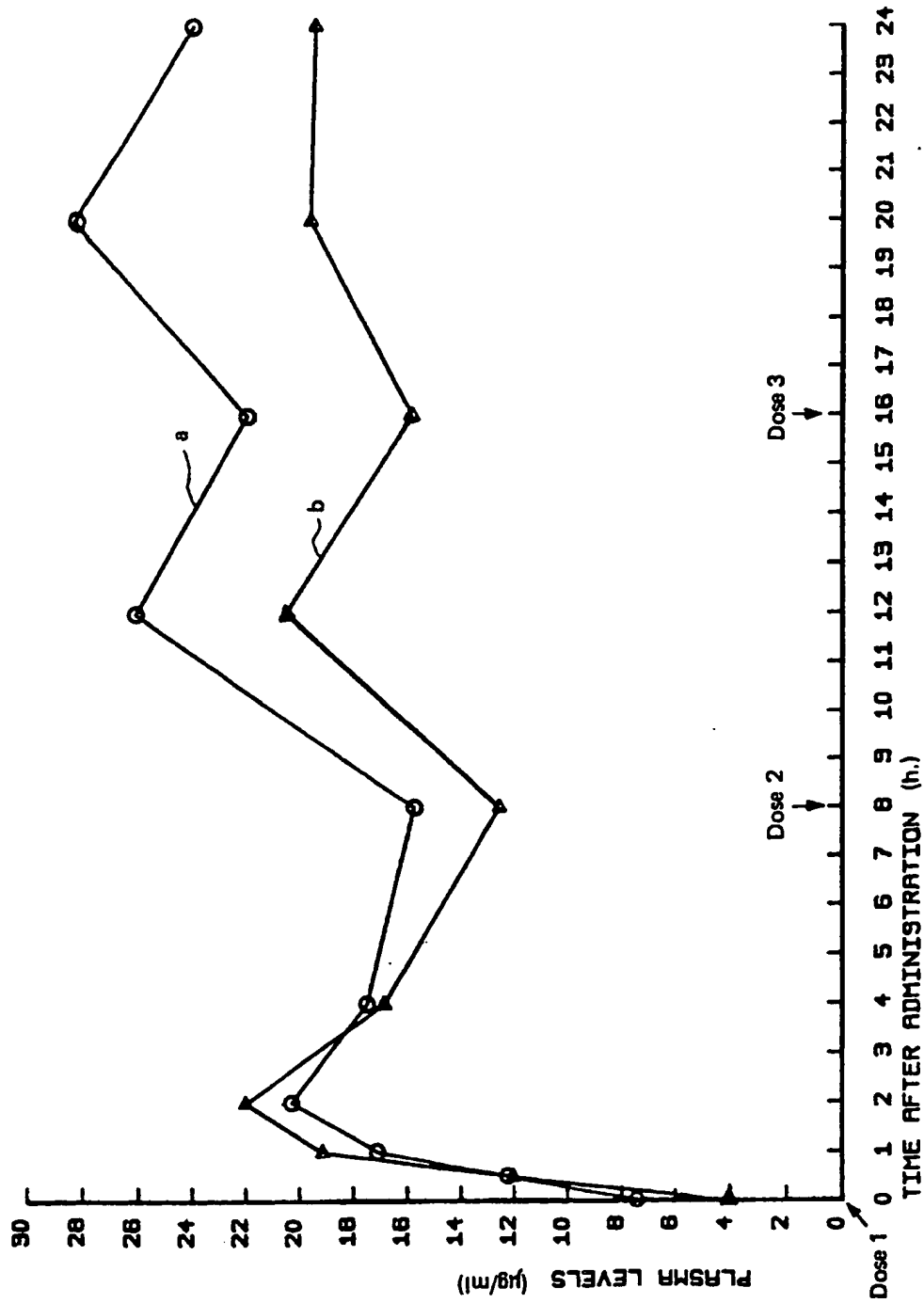


FIG. 2



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Patent Office

## EUROPEAN SEARCH REPORT

Application Number

EP 90 31 1738

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	EP-A-0 232 155 (ELAN) * Claims 1,4,6-7,11-14; column 2, lines 56-57; column 4: example 1 * - - - -	1,6-8,10	A 61 K 9/18 A 61 K 31/565
A	EP-A-0 274 176 (ELAN) * Claims 1,6-9; page 4, example 1 * - - - -	1,6-8,10	
A	GB-A-2 153 677 (FARMITALIA) * Claims 1,3-4,6-11; page 4, example 7 * - - - -	1,6-8,10	
A	EP-A-0 163 178 (BEECHAM) * Claims 1,5-8,10; page 6, example 1 * - - - - -	1,6-8,10	
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of search 31 January 91	Examiner SCARPONI U.
<div><div><b>CATEGORY OF CITED DOCUMENTS</b> X: particularly relevant if taken alone Y: particularly relevant if combined with another document of the same category A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention</div><div>E: earlier patent document, but published on, or after the filing date D: document cited in the application L: document cited for other reasons ----- &amp;: member of the same patent family, corresponding document</div></div>			